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On the working regime of a pulsed duopigatron ion source

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A pulsed duopigatron ion source operated in hydrogen atmosphere is investigated. Plasma parameters were determined using a plane Langmuir probe. Experimental observations of self oscillations occurring in one of the two working regimes were put into evidence. The development of the self- oscillations depending on the gas pressure and magnetic field intensity was analysed.

Introduction

Most common devices used to observe a rich variety of phenomena in collisionless plasma discharges are plasma sources with magnetic field and hot emissive filaments as cathodes. Nowadays there is an increasing interest in studying pulsed ion sources as the duopigatron one, because of their behavior presenting self excited oscillations or chaotic patterns depending on some external parameters.

The aim of this work is to analyze the influence of the gas pressure and of the magnetic field intensities on the characteristics of the self-oscillations developed in the pulsed duopigatron source.

Results and discussion

The classical configuration (hot cathode-intermediate electrode-reflecting electrode anode) of a pulsed duopigatron ion source was used to investigate the transition from a chaotic pulsed plasma towards the development of self-excited oscillations with a frequency of 25÷30 kHz. The cathode of the duopigatron ion source is supplied continuously and a negative electrical pulse (10 Hz, 250 μs duration) is applied to the cathode anode gap [1]. The intermediate and the reflecting electrodes are biased automatically via serial resistors.

The ion source was operated mainly in 99.99% hydrogen atmosphere, but other gases (N_2, O_2, Ar) were used during the investigations. The pressure working regime was in the range $5.10^{-5} \div 6.10^{-3}$ mbar.

The dense, pulsed plasma expands into the working chamber where it was investigated. The discharge current is max. 30 A at a frequency of 1 ÷ 10 Hz, with a 20 ÷300 μs pulse duration. A plane Langmuir probe was used to determine carrier concentration, electron temperature and plasma potential in a cylindrical volume around the axis of the working chamber. To investigate the time evolution of the expanding plasma, the probe characteristics were determined using a digitising oscilloscope and a data acquisition system.

Two working regimes of the ion source were evidenced. In the normal one (for pressures higher than 10^{-4} mbar) the discharge current displays a normal rectangular shape with the same pattern as the applied pulsed voltage. Fig.1 illustrates the shape of the voltage and the discharge current as obtained on the oscilloscope display at a pressure of 1.9×10^{-3}mbar.

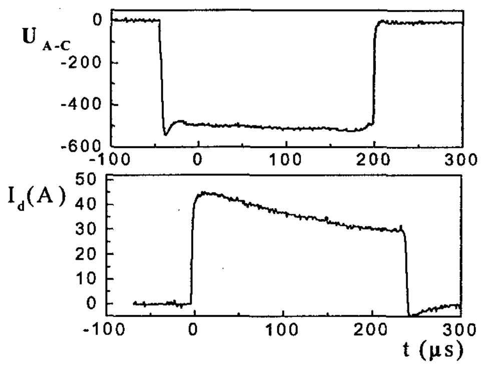

Fig.1 The shape of the voltage U_{A-C} and the discharge current pulse I_d at a pressure of 1.9×10^{-3} mbar

At relatively high pressures ($p>10^{-3}$ mbar) the plasma characteristics display a continuous variation during the discharge pulse, as presented in Fig. 2 for electron density/ temperature and in Fig. 3 for plasma potential.

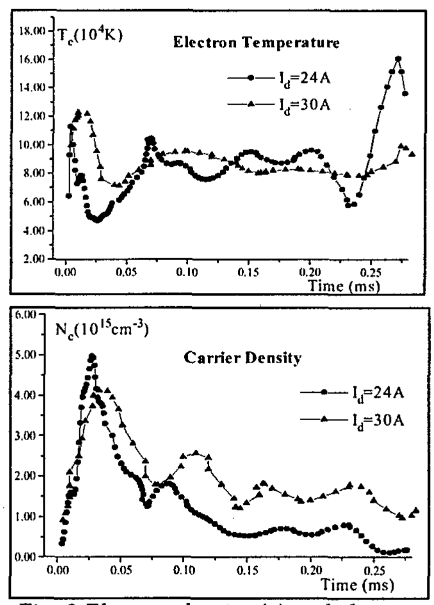

Fig. 2 Electron density (a) and electron temperature(b) variation during the discharge pulse

The analysis reveals that during pulse duration all these parameters reach a maximum with a delay of about

1÷2μs from the applied pulse. The plasma potential and the electron temperature show a saddle pattern in the middle of the impulse and a sharp increase at the pulse end. The increase of electron temperature and plasma potential after the driving pulse cut-off may be ascribed to the destruction of the double layer structure located nearby the anode, which suddenly transfers its energy to the plasma.

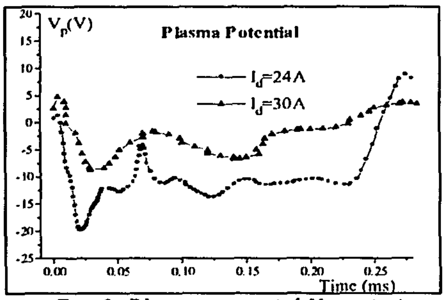

Fig. 3. Plasma potential V_p variation during the discharge pulse

In the lower pressure regime ($p<10^{-4}$ mbar) self excited oscillations of the discharge current during the applied pulsed voltage are exhibited, independently of the gas nature, pulse frequency and duration. The occurence and the shapes of these oscillations present a great dependence on the gas pressure (Fig.4). The amplitude of the oscillations of the discharge current is limited by the filament temperature ("temperature limited current regime"[4]), being slightly dependent on the discharge voltage and not strongly dependent, as reported in [3].

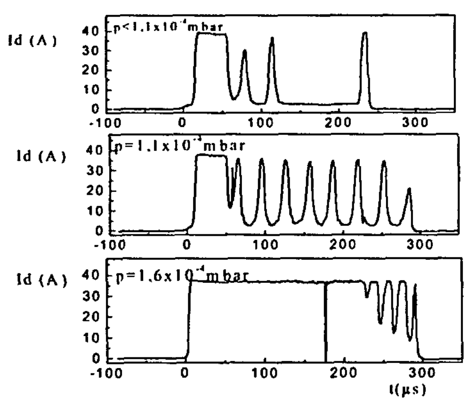

Fig. 4. Shape of the discharge current at different H_2 working pressure

As it was already reported [2], [3], plasmas produced in devices with thermoemission and applied external magnetic field may present under certain conditions an oscillating behaviour, mainly due to a lack of carriers in front of the electrodes where a double layer is formed. In our configuration, self-oscillations are developing in a narrow pressure range: 1.6×10^{-4} mbar ÷ 1.1×10^{-4}mbar. At a certain pressure (1.2×10^{-4} mbar) the oscillations exhibit a structured sinusoidal form, far from the chaotic appearance exhibited at higher pressures. In Fig.5 the correlation between the oscillating feature of the discharge current I_d and the anode voltage can be seen: the anode voltage measured with respect to the ground presents minima corresponding to the maxima in the discharge current.

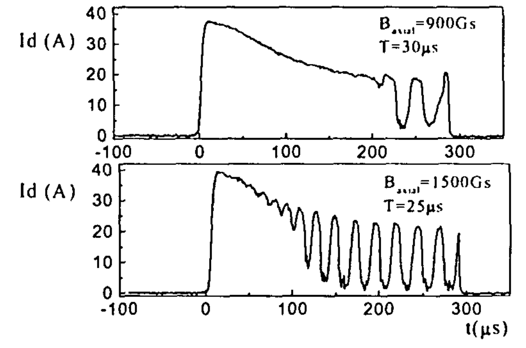

Fig. 5 Correlation between anodic voltage (U_a) and discharge current (I_d), $p=1.2\times10^{-4}$ mbar

The increase of the magnetic field, accompanied by a reduced charged particle loss to the walls at low electron densities determine the development of the oscillations through the entire pulse duration. Different oscillations corresponding to 900 Gs and 1500 Gs are presented in Fig. 6. The self-oscillations develop as distinctive patterns from the beginning towards the end of the pulse, as the magnetic field intensity increases.

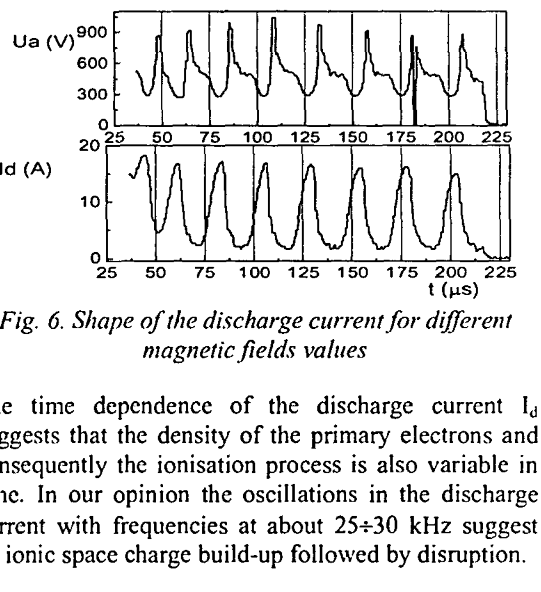

Fig. 6. Shape of the discharge current for different magnetic fields values

The time dependence of the discharge current I_d suggests that the density of the primary electrons and consequently the ionisation process is also variable in time. In our opinion the oscillations in the discharge current with frequencies at about 25÷30 kHz suggest an ionic space charge build-up followed by disruption.

Conclusions

The investigation of a pulsed duopigatron ion source evidenced the development of self excited oscillations with 25÷30 kHz at low pressures and high magnetic fields, determined by an ionic space charge build-up followed by disruption.

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